

SEARCH FOR HEAVY PARTICLE IN HADRONIC INTERACTIONS

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Studies of the form of nuclear-cascade avalanches in an ionization calorimeter and the noted peculiarities in their behavior have suggested to us the possible generation of a heavy unstable particle when high-energy hadrons interact with atomic nuclei.

We undertook a search for such a particle (which we shall call T-particle) under the conditions of our experiment, performed at the Aragats station at an altitude 3260 m above sea level. A detailed description of the installation can be found in [1, 2].

The geometric factor of the ionization calorimeter, which consisted of 16 rows of ionization chambers interlined with iron and 6 rows pairwise lined with lead, was 2800 cm²-sr. The registration system permits a pulse-height analysis from 266 ionization detectors. Each ionization chamber measured 10 cm, making it possible to trace the core of the avalanche in the calorimeter, and the large number of detector layers made it possible to determine the dynamics of cascade development in depth. The energy E_0 of the particle incident on the calorimeter was determined from the summary ionization released in the calorimeter.

We have assumed that the T-particle mass $M_T > 10$ GeV that this particle is unstable, and that its free path for the interaction with the atomic nuclei, with transfer of noticeable energy to the π^0 mesons, is much longer than the corresponding path for protons. If such a particle is generated by interaction with iron nuclei in the ionization chamber, then the plots of the nuclear cascade will have two maxima each. However, nuclear cascades of the same type can occur also when the nucleon or pion incident on the setup transfers to the secondary particles only a fraction of its energy in the first interaction. It is possible to discriminate between these two cases by studying the behavior of the distance \bar{l} between the starts of the first and second cascades as a function of the energy E_2 of the secondary particle, E_2 being defined as the summary energy of all the succeeding cascades.

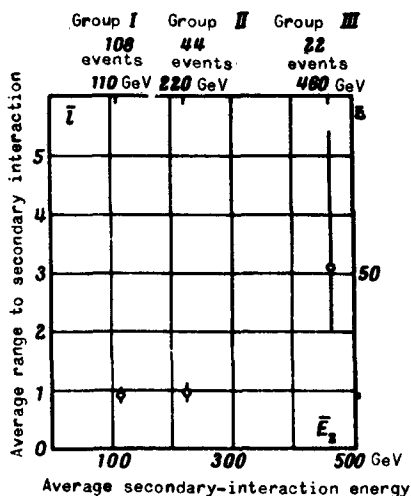


Fig. 1. Plot of \bar{l} against E_2 .

If a T-particle is generated, then \bar{l} is equal to its decay free path. In the other case $\bar{l} = \bar{l}_{int}/n$, where \bar{l}_{int} is the free path for the interaction of the hadron with the iron nuclei and is independent of E_2 , while n is the number of secondary hadrons with energy $> 0.2E_0$.

Out of 2000 events with energy > 100 GeV, we selected for the analysis about 200 interactions satisfying the following conditions:

1. The start of the nuclear cascade lies within the limits of the ionization calorimeter.

2. The nuclear cascade has at least two distinguishable maxima.

3. $E_2 > 0.5E_0$, and in addition $E_2 > 10\gamma_C$ GeV, where γ_C is the Lorentz factor of the

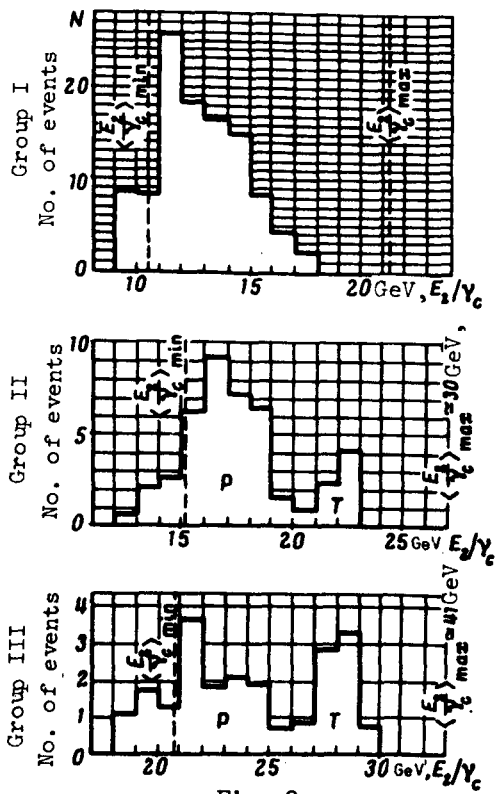


Fig. 2

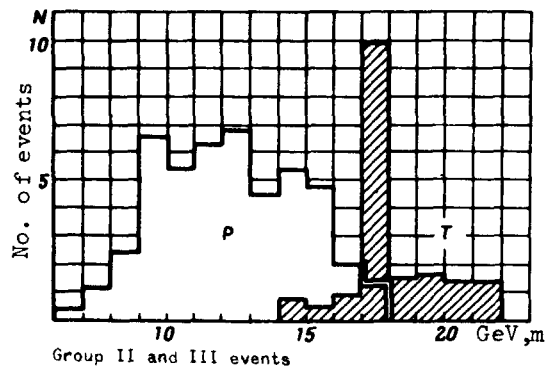


Fig. 3

Fig. 2. Distribution of the events with respect to E_2/γ_C ; $(E_2/\gamma_C)_{\min}$ and $(E_2/\gamma_C)_{\max}$ are the limits determined by the selection of the events.

Fig. 3. Mass distribution after allowance for the motion of the T-particle in the C system.

C system for NN collisions.

The maxima can then be reliably distinguished if the distance between the generation points exceeds two rows.

The selected showers were divided into three groups: group I - $E_2 < 170$ GeV, 108 events, and $\bar{E}_2 = 110$ GeV; group II - $170 < E_2 < 300$ GeV, 44 events, and $\bar{E}_2 = 220$ GeV; group III - $E_2 > 300$ GeV, 22 events, and $\bar{E}_2 = 460$ GeV.

The measured free paths $\bar{\ell}_i$ were averaged over the groups

$$\bar{\ell} = \sum k_i \bar{\ell}_i / \sum k_i, \text{ where } k_i = (E_{0i} / 100 \text{ GeV})^{\gamma-1}.$$

The normalization factor k_i was introduced to eliminate discrimination of the events by energy (γ is the exponent of the energy spectrum of the nuclear active particles, $\gamma - 1 = 1.75$). In the calculation of $\bar{\ell}$ we took into account the finite dimensions of the calorimeter and the real dimensions of the nuclear cascade in the calorimeter.

Figure 1 shows the dependence of the mean value of $\bar{\ell}$ on the energy \bar{E}_2 for the three groups of events. Notice should be taken of the fact that $\bar{\ell}$ increases with \bar{E}_2 .

If the T-particle is produced in a nuclear interaction and carries away an energy E_2 , then its mass can be estimated by assuming that near the production threshold it moves in the C-system with a low velocity and has a Lorentz factor γ_C . Then $M_T = E_2/\gamma_C$.

Figure 2 shows the distributions of the events with respect to E_2/γ_C for the three groups indicated above. Whereas the distribution for group I has a

more or less smooth character, the distributions for the other groups reveal irregularities in the region $E_2/\gamma_C > 20$ GeV for group II and in the region $E_2/\gamma_C > 25$ GeV for group III. It can be assumed that their appearance is due to the T-particle, whose mass can then be estimated. It follows from Fig. 2 that $M_T \lesssim 22$ GeV/c². If the additional irregularity in the E_2/γ_C distribution is connected with the motion of the particle in the C-system, then its mass with allowance for this motion is 18 ± 4 GeV/c² (Fig. 3).

A subsequent analysis has shown that the entire growth of $\bar{\lambda}$ is due to the events causing the irregularities in the distribution with respect to E_2/γ_C . In all the remaining cases, no significant growth of $\bar{\lambda}$ is observed. From the value of $\bar{\lambda}$ for the T-particles we can estimate their lifetime:

$$\tau_T = 4 \cdot 10^{-11} \text{ sec}$$

From the frequency of the T-particle appearances we estimated their production cross section in the energy interval 400 - 800 GeV, namely $\sigma_T \sim 15$ mb.

This is 2% of the inelastic cross section for the interaction of the nucleons with the iron nuclei. We have carried out the investigation near the T-particle production threshold, and it is thus to be expected that their production cross section will increase rapidly with increasing energy, and their number will turn out to be sufficient to explain a number of effects observed presently in cosmic rays. We have in mind the experimental facts that find no explanation within the framework of the customary concepts, such as the change of the slope of the primary spectrum of the cosmic protons, as registered with the "Proton" satellites [3] and in the spectra of nuclear-active particles deep in the atmosphere [4], the variation of the inelasticity coefficient $k_{\pi 0}$ with increasing primary-particle energy [5], and several others. All these effects were obtained in measurements with installations of the calorimetric type, having different thicknesses, and can be easily understood if our hypothesis regarding the generation of a heavy unstable particle is correct.

Analogous considerations with respect to the explanation of some of the effects noted above have been advanced in [6].

We are continuing a methodological analysis of our results on the basis of extensive statistical material. Although we still do not see any other possibility of explaining the observed effect, other than the hypothesis that a new particle exists, the fundamental character of these conclusions causes us to approach with caution the foregoing interpretation, which may not turn out to be unique.

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